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PROCEDURES FOR REGIONAL ASSESSMENT OF HABITATS FOR SPECIES OF CONSERVATION CONCERN IN THE SAGEBRUSH ECOSYSTEM

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Appendix 2: Identifying Species of Conservation Concern in the Sagebrush Ecosystem

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EXECUTIVE SUMMARY

Rationale and Purpose

We developed procedures for regional assessment of habitats for species of conservation concern (species with declining or rare habitats or populations, also called species of concern) in the sagebrush (*Artemisia* spp.) ecosystem. We define a regional assessment as a spatial or temporal analysis of environmental conditions for species of conservation concern that is conducted for areas typically encompassing ≥100,000 hectares (≥250,000 acres), and often encompassing areas >1 million hectares (>2.5 million acres). Our procedures are designed to assess environmental conditions for species whose habitats can be mapped accurately over these large areas. Consequently, our working definition of habitat is the cover types on which a species depends, for those species whose associated cover types can be mapped accurately for areas typically encompassing ≥100,000 hectares.

Cover types and associated alliances, such as those defined under the vegetation classification system of Reid et al. (2002) and used by Comer et al. (2002) for mapping sagebrush, meet our working definition of habitats for regional assessment of species of concern (see *Glossary* [Appendix 1] for definitions of terms used in this document). By contrast, local habitats in small or restricted areas are not included as part of our procedures, as such habitats cannot be mapped accurately as cover types in regional assessments. Consequently, species of conservation concern that are local endemics, whose habitats by definition can be assessed only with local knowledge, are not addressed in this document.

Our procedures were developed for consistent and credible application on federal lands in ecoregions containing sagebrush in the western United States (Figure 1, Table 1). Ecoregions have been identified and mapped by The Nature Conservancy (TNC) (Groves et al. 2000; http://gis.tnc.org/data/MapbookWebsite/map_page.php?map_id=9). Ecoregions dominated by sagebrush include the Columbia Plateau, Great Basin, Wyoming Basins, and adjacent areas (Figure 1). These ecoregions encompass the sagebrush ecosystem, defined by Comer et al. (2002) as 43 million hectares (106 million acres) of sagebrush-dominated lands in the western United States, the boundaries of which closely follow those of the historical range of Greater sage-grouse (*Centrocercus urophasianus*) and Gunnison sage-grouse (*C. minimus*) (Figures 1, 2).

Procedures outlined here are needed because of the prospect of continued and extensive habitat and population declines for many species associated with the sagebrush ecosystem (Knick 1999, Paige and Ritter 1999, Miller and Eddleman 2000), and the resulting high risk of regional extirpation for many species (Raphael et al. 2001). In particular, there is a compelling and unmet need for regional assessment procedures that address, in a holistic manner, the environmental threats associated with habitats for sagebrush-associated species. Knowledge gained from such assessments can be used to guide conservation and restoration planning for sagebrush habitats, holistically and efficiently across large areas, as part of ecosystem management.

Our procedures are presented as analytical steps. The steps are designed to evaluate a comprehensive set of species, and to allow efficient application with spatial data currently available as continuous coverages across the sagebrush ecoregions. We also illustrate the application of our procedures in an example, prototype assessment for the Great Basin

Ecoregion, as described in a companion document available in summer of 2003 (Wisdom et al. 2003).

Regional habitat assessments are essential in establishing regional management strategies as context for efficient and credible development and implementation of local land use plans. At the same time, regional management strategies can be refined with feedback from local planning. The interaction of regional management strategies with local planning fits the concept of "top-down" and "bottom-up" processes (Figures 3, 4). Both processes are essential in addressing land use issues that are both regional and local in scale. Accordingly, we assume that results of regional assessments will be considered in tandem with finer-scale evaluations of habitats as part of local management. Ultimately, the utility of regional assessments depends largely on the successful integration of both regional and local management strategies and their implementation.

Goals, Objectives, and Analytical Steps of Regional Habitat Assessments

An effective regional assessment requires clear goals, objectives, and supporting analytical steps. An example of a compelling, over-arching goal for species of conservation concern is to gain regional knowledge about species' habitats for effective use in maintaining or improving the probability of habitat and population persistence. Key objectives can be tiered to such goals, such as the following examples: (1) identify and evaluate habitats for a comprehensive set of species of conservation concern in sagebrush ecoregions; (2) evaluate trade-offs between management for individual species versus a comprehensive set of species; (3) summarize results at desired scales; and (4) provide guidance about use of results for effective multi-species planning.

In support of such example objectives, the following steps can be used for effective regional assessment. Because the sagebrush ecosystem continues to experience swift and extensive loss and degradation of habitats, we emphasize steps that focus on threats to existing habitats, and the risks posed by each threat. These steps, described in detail later, are designed for spatial analysis in sagebrush ecoregions during the current time period.

Example steps are:

(1) identify the ecoregion and associated spatial extents for regional assessment;
(2) identify species of conservation concern in the ecoregion;
(2) delineate species ranges;
(3) estimate habitat requirements of species;
(4) identify regional threats and effects of such threats on habitats;
(5) estimate and map the risks of habitat loss or degradation posed by each threat;
(6) calculate species-habitat effects from risks of all threats;
(7) form species groups to generalize results across species;
(8) summarize results for species and groups at desired spatial extents; and
(9) list major assumptions, limitations, and guidelines for management.

Importantly, procedures that focus on threats to habitats are of high utility for the design and implementation of appropriate conservation and restoration practices. For example, mapping sagebrush habitats that are highly vulnerable to invasion by cheatgrass (*Bromus tectorum*), versus areas highly vulnerable to encroachment by pinyon-juniper (*Pinus* spp. and *Juniperus* spp.) woodlands, provides spatially-explicit knowledge needed to target each threat

with the appropriate management prescriptions, and to estimate the area, time, and resources required to apply the prescriptions. Alternatively, mapping areas where such threats are not imminent allows managers to understand where fewer resources may be needed. Knowledge of threats to habitats can be used for multi-species evaluations, described later.

Our procedures are built on the assumption that habitats for species of concern can be assessed at regional scales, using the recently completed 90-meter by 90-meter (0.81 hectare, or 2 acres) pixel map that composes the "sagestitch" layer (referred to here as the 90-m sagestitch map [Comer et al. 2002, Reid et al. 2002]). The sagestitch map layer currently provides the only continuous coverage of sagebrush across the entire sagebrush ecosystem (Figure 1). Accuracy of the 90-m sagestitch map is considered sufficient to assess habitats at coarse resolution for species of concern at spatial extents of an ecoregion, and for ecological provinces, subbasins, or other large spatial extents nested within each ecoregion (Figures 3, 4). Our procedures also can be applied with more accurate vegetation layers of large spatial extents, such as the 30-meter by 30-meter pixel map of sagebrush cover types now under development (Comer et al. 2000).

INTRODUCTION

Status of the Sagebrush Ecosystem

The sagebrush ecosystem occupies 43 million hectares of semi-arid, sagebrush-dominated lands in the western United States (Table 1). As such, this vast area composes one of the largest ecosystems in North America (Center for Science, Economics and Environment 2002). Although the sagebrush ecosystem remains large, it has been substantially reduced in area and quality. Causes for loss and degradation are many and varied. Invasion of exotic vegetation, altered fire regimes, road development and use, mining, energy development, climate change, encroachment of pinyon-juniper woodlands, intensive grazing by livestock, and conversion to agriculture, to urban use, and to non-native livestock forage all have contributed to the ecosystem's demise (Noss et al. 1995, Tausch et al. 1995, Knick 1999, Miller and Eddleman 2000, Bunting et al. 2002).

The combination of detrimental land uses and undesirable processes has prompted scientists to identify the sagebrush ecosystem as one of the most endangered in the United States (Noss et al. 1995); almost 20% of all plants and animals associated with such systems may be at risk of extirpation (Center for Science, Economics and Environment 2002). Millions of hectares of the ecosystem have been altered or eliminated during the past century (Hann et al. 1997, West 1999), and <10% of the ecosystem remains unaltered by human activities (West 1999). Moreover, loss and degradation on federal lands, where most native sagebrush remains, is increasing rapidly (Hemstrom et al. 2002).

As a consequence, federal land managers are increasingly concerned about the fate of the sagebrush ecosystem and its associated species. A variety of scientific assessments have documented the myriad problems in the ecosystem (Hann et al. 1997, West 1999, Miller and Eddleman 2000), yet efforts to halt or reverse loss and degradation have been unsuccessful at large scales (West 1999, Hemstrom et al 2002). In particular, cheatgrass and other exotic plants continue to displace native sagebrush communities following intensive grazing and large, intense wildfires (Billings 1994, Hann et al. 1997, Bunting et al. 2002), and this form of habitat loss is accelerating on federal lands (Hemstrom et al. 2002). Calls for more intensive, sustained, and

extensive conservation and restoration efforts in the ecosystem are growing, coupled with the realization that such efforts require monumental spatial and temporal scales of application to be effective (Knick 1999, Bunting et al. 2002, Hemstrom et al. 2002).

Perhaps the most notable indication of problems in the sagebrush ecosystem has been the significant and continuing decline in habitats and populations of Greater sage-grouse (Connelly and Braun 1997; Schroeder et al. 1999). A variety of detrimental land uses pose major threats to this species' persistence (Schroeder et al. 1999; Connelly et al. 2000; Raphael et al. 2001; Hemstrom et al. 2002; Wisdom et al. 2002*a, b*). New guidelines were developed recently (Connelly et al. 2000) to help managers conserve and restore habitats for the species at the stand scale, but similar guidelines do not exist for regional scales that encompass all or major portions of the species' range. The cumulative effects of management at these large scales can greatly influence the likelihood of regional extirpation of sage grouse (Raphael et al. 2001). Moreover, recent research over extensive sagebrush landscapes (Wisdom et al. 2000; Raphael et al. 2001; Hemstrom et al. 2002; Wisdom et al. 2002*a, b, c*) has provided new and compelling knowledge about status, trends, and risks for sage-grouse habitat that could be used for effective conservation and restoration planning across the species' range.

In addition to sage grouse, many plants and animals are associated with the sagebrush ecosystem and are of conservation concern. Wisdom et al. (2000) identified 30 species of vertebrates in the Interior Columbia Basin that are closely associated with sagebrush habitats, and that are of concern because of declining or rare habitats or populations. Suring et al. (in prep.) recently identified >350 species of sagebrush-associated plants and animals of conservation concern within the historical range of sage grouse (Figures 2, 5, Appendix 2). Similar lists have been developed by State Natural Heritage Programs and by state and federal agencies. Yet, few procedures have been developed and applied to efficiently assess regional habitats for individual species of concern, such as sage grouse, in concert with regional habitat assessment of a comprehensive set of species associated with the sagebrush ecosystem. These procedures are urgently needed by the USDI Bureau of Land Management (BLM), USDA Forest Service (FS), and USDI Fish and Wildlife Service (FWS) to gain regional knowledge for effective conservation and restoration of sagebrush habitats, owing to the high likelihood of regional extirpation events for many sagebrush-associated species (Raphael et al. 2001).

Distribution and Abundance of Sagebrush at Regional Scales

We define the sagebrush ecosystem (Figure 1) as semi-arid, sagebrush-dominated lands in the western United States that encompass the approximate boundaries of the historical range of Greater sage-grouse and Gunnison sage-grouse (Figure 2). The SAGEMAP Project, when established, focused on the collection and dissemination of spatial data layers that occur within the historical range of sage-grouse (http://sagemap.wr.usgs.gov; Comer et al. 2000). Our work is designed to use many of the spatial layers available from SAGEMAP. Consequently, the spatial extent of the sagebrush ecosystem used in our work follows that defined by SAGEMAP.

Ten sagebrush cover types, spanning 19 ecoregions in the western United States were delineated in the 90-m sagestitch map recently completed by the SAGEMAP Project (Table 1; Comer et al. 2002). Although 19 of the ecoregions defined by TNC contain sagebrush, three ecoregions—Columbia Plateau, Great Basin, and Wyoming Basins—support the majority (70%) of area in these cover types (Table 1). The Columbia Plateau and Great Basin Ecoregions, in

particular, support >50% of all remaining sagebrush, with extensive concentrations in northern Nevada, southeastern Oregon, and southwestern Idaho (Table 1; Figure 1).

Extensive and large concentrations of sagebrush also are evident throughout the state of Wyoming, encompassing the Wyoming Basins Ecoregion and the southern portion of the Northern Great Plains Steppe Ecoregion. Miller and Eddleman (2000) describe the distribution and ecology of the sagebrush ecosystem, and Reid et al. (2002) describe the recently revised classification of sagebrush alliances and associations.

Objectives of this Document

In response to the urgent need to conserve and restore habitats at regional scales in the sagebrush ecosystem, our objectives were to (1) identify regional assessment procedures that can be used efficiently and credibly to evaluate conditions for a comprehensive set of species of conservation concern in the sagebrush ecoregions, with emphasis on federal lands and the needs of federal land managers; (2) develop methods by which trade-offs between the needs of individual species versus a comprehensive set of species can be addressed systematically and defensibly at regional scales for land use planning; (3) demonstrate the use of regional assessment procedures with spatial data currently available as continuous coverages across all sagebrush ecoregions (Figure 1); and (4) provide guidance regarding use of the procedures for effective multi-species planning at regional versus local scales as part of ecosystem management.

As context for our procedures, we provide examples of regional assessments recently completed for species of concern in other, non-sagebrush ecosystems (Appendix 3). We also illustrate the application of our procedures in a companion document (Wisdom et al. 2003) that features an example, prototype assessment for species of conservation concern in the Great Basin Ecoregion of California, Nevada, and Utah (Figure 1). These procedures and their prototype application will help guide conservation and restoration planning for sagebrush-associated species on federal lands in the sagebrush ecosystem.

Our procedures are designed to complement related work for sagebrush habitats and associated species, such as the SAGEMAP Project (http://sagemap.wr.usgs.gov) led by USDI Geological Survey (USGS), the Great Basin Restoration Initiative led by BLM (USDI Bureau of Land Management 1999), ecoregion assessments by TNC (e.g., Freilich et al. 2001, Nachlinger et al. 2001), state-level conservation strategies for sage-grouse and associated habitats (e.g., Canadian Sage Grouse Recovery Team 2001; Neel 2001; Anonymous 1997), and local assessments underway by BLM and FS. Implementation of our procedures also would provide state agencies with new, regional information to help meet their goals related to sagebrush-associated species. The procedures and prototype assessment also are designed to coordinate with interagency committees on sage grouse and sagebrush management, and will be available for use by these committees to meet interagency needs of federal and state agencies.

Target Audience

The primary audience for this document consists of resource specialists, spatial analysts, and scientists with backgrounds in landscape ecology, conservation biology, and spatial assessment. This primary audience, because of their expertise, is presumed to be familiar with

the concepts, terms, and basic approaches outlined here, but not necessarily familiar with the details described here for sagebrush-associated species of concern. Owing to their expertise, we assume that this primary audience could apply our procedures in a credible and defensible manner for regional assessment of habitats for species of concern in the sagebrush ecosystem.

A secondary audience, for sections on why regional assessments are needed, and for general information in other sections, includes resource managers and resource specialists in state and federal agencies, tribal nations, and private organizations who administer management programs for species of conservation concern, but who have less experience in the subject areas listed for the primary audience. This secondary audience is not expected to understand all concepts, terms, and procedures in full detail. Such understanding requires prior working experience on regional assessments or regional mapping; providing adequate details to ensure understanding by all resource managers and specialists is beyond the scope of this document. The comprehensive list of literature cited in this report can be referred to for a fuller understanding of materials presented here.

Importantly, the secondary audience is expected to be the primary user of results from the application of our procedures. Effective use of such results is the ultimate expectation that prompted development of our paper.

WHY CONDUCT REGIONAL SAGEBRUSH ASSESSMENTS?

A regional habitat assessment, as defined here, is a spatial or temporal analysis of environmental conditions for species of conservation concern conducted for areas typically encompassing 100,000 hectares or larger, and often encompassing areas >1 million hectares (see example regional assessments, Appendix 3). The need for regional assessment of sagebrush habitats for species of concern is based on five points:

1. Habitats and populations of sagebrush-associated species continue to decline across vast areas. The prospect of continued habitat and population declines for sagebrush-associated species (Knick and Rotenberry 1999, 2000; Paige and Ritter 1999; Wisdom et al. 2000) across large areas, and the associated high risk of large-scale extirpation events for these species (Raphael et al. 2001), point to the urgent need for regional assessments. Use of regional assessments can capture these top-down processes that manifest over vast areas, allowing for greater management efficiencies.

2. The number of sagebrush-associated species of concern is daunting, and many of these species have extensive ranges compatible with regional assessments. Hundreds of species of conservation concern are associated with sagebrush habitats (Suring et al. in prep., Figure 4), illustrating the need for holistic assessment procedures that can efficiently serve management needs of all species. In addition, many of these species have ranges that encompass millions of hectares and span multiple states and administrative units. Habitat conditions across these wide ranges cannot be managed effectively or efficiently if each BLM Field Office or National Forest is assessed and managed independently of one another. Evaluation of habitat at broad scales provides information to be considered in development of regional management strategies, such as the Great Basin Restoration Initiative by BLM (USDI Bureau of Land Management 1999).

Such strategies can serve as an "umbrella," under which local land use plans can evolve in a consistent and efficient manner, while still adhering to local needs and conditions.

3. Threats to sagebrush habitats are regional in scale. Invasion by exotic plants, ineffective suppression of undesirable wildfires, road development and use, mining, energy development, and other detrimental processes in sagebrush habitats are not local, isolated events. Instead, the processes that pose threats to sagebrush habitats occur across large areas, with cumulative effects that pose high risks to persistence of sagebrush-associated species. Pervasive, regional threats to habitats are best addressed at regional scales, which allow the cumulative effects of a variety of threats to be addressed consistently and holistically across large areas.

4. Regional knowledge facilitates development of consistent, efficient, and credible regional management strategies for a comprehensive set of species. If threats to sagebrush habitats are regional in scale, then regional knowledge of these threats and the underlying processes is needed to develop regional strategies that can address these problems efficiently, consistently, and credibly across large areas. The alternative is local plans that address local problems with local solutions, but by definition are not designed to address threats to habitats consistently across multiple planning areas in an ecoregion. In particular, there is an unmet need for regional assessments that address, in a holistic manner, the conditions and threats associated with a comprehensive set of species associated with sagebrush habitats. Such an approach was developed recently as part of a regional habitat network for sagebrush-associated species in the Interior Northwest (Wisdom et al. 2002*c*). This type of large-scale, multi-species approach would be useful as part of regional assessments for conservation and restoration planning in all sagebrush ecoregions.

5. Regional knowledge provides essential context for local land use planning. Land use plans for individual National Forests or BLM Field Offices depend on defensible justification as to why particular management issues are of interest and focus. Local needs and issues are obvious topics for planning within a National Forest or BLM Field Office. The addition of regional knowledge, however, provides essential context for, and complements, local planning issues. Neither regional knowledge nor local knowledge is independent in terms of land use planning. That is, regional knowledge can identify the dominant spatial and temporal patterns that manifest consistently across large areas, referred to as "top-down" processes (Peterson and Parker 1998). These patterns are in contrast to the finer patterns unique to local areas and conditions, referred to as "bottom-up" processes. Both sets of processes (Figures 3, 4) must be addressed for effective conservation and restoration of sagebrush habitats, described later.

WHY FOCUS REGIONAL SAGEBRUSH ASSESSMENTS ON FEDERAL LANDS?

Managers of federal land are uniquely positioned and responsible for management of habitats for sagebrush-associated species for 2 main reasons:

1. Most remaining sagebrush habitats occur on federal lands, and habitat loss and degradation on these lands are substantial and accelerating. As stated earlier, the sagebrush ecosystem has been characterized as critically endangered (Noss et al. 1995). Nearly 70% of the

ecosystem is managed by state or federal agencies, with almost 65% under federal control (Table 2). The BLM and FS administer most of the sagebrush under federal management, managing 52% and 9%, respectively, of all existing sagebrush. These patterns emphasize the key role of federal land management in the conservation of biological diversity in the sagebrush ecosystem and adjacent ecosystems (Stein et al. 1995). While historically most losses of sagebrush habitat occurred on non-federal lands, such losses are currently accelerating on federal lands. Future loss and degradation of sagebrush on federal lands are projected to accelerate, owing to a variety of detrimental processes and land uses (Hemstrom et al. 2002).

2. Federal land managers have legal responsibilities for effective management of habitats for sagebrush-associated species of conservation concern. Responsibilities of federal agencies to conserve and restore species of conservation concern and their habitats are well defined in legislation and policy (Appendix 4). The Federal Land Policy and Management Act (FLPMA) directs the BLM to provide habitat for fish and wildlife and to protect the quality of ecological values. BLM has a variety of policies, based on FLPMA, that are designed to conserve federally and state listed species and their habitats, and to develop and implement effective restoration strategies for such species (Appendix 4). Similarly, the National Forest Management Act (NFMA) directs the USDA Forest Service to "...provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives..." In regulations developed to implement NFMA, the following direction is provided: "Fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area" (Appendix 4). Similar direction is provided to the FWS in managing National Wildlife Refuges: "In administering the [National Wildlife Refuge] System, the Secretary shall . . . ensure that the biological integrity, diversity, and environmental health of the System are maintained..." (Appendix 4). The FWS also administers the Endangered Species Act, whose premise is based on preemptive management designed to prevent federal listings of species, a concept directly pertinent to conservation and restoration of habitats for species of conservation concern in the sagebrush ecosystem (Appendix 2). The U.S. Department of Defense (DOD) also has legal and policy direction to balance military activities on DOD lands with biological diversity (Appendix 4).

SETTING GOALS AND OBJECTIVES IN THE CONTEXT OF SPATIAL AND TEMPORAL SCALES OF ASSESSMENT

An effective regional assessment requires clear goals and objectives. As mentioned earlier, an example of a compelling, over-arching goal for a regional assessment of habitats for species of conservation concern is to gain regional knowledge about these species' habitats for effective use in improving the probability of habitat and population persistence. Regardless of specific goals and objectives, completion of the process of setting the goals and objectives is critical. Without explicit goals and objectives, direction for the regional assessment will be unclear, and its intended benefits may not be realized.

When defining goals and objectives, consideration of spatial scale is essential (Maurer 2002). Spatial scale is characterized by extent, grain, and accuracy (Figure 3, Peterson and Parker 1998). Extent refers to the size and boundaries of the area under evaluation. For

example, the spatial extent of an ecoregion follows ecological boundaries and encompasses millions of hectares, in contrast to an individual patch that may occupy <1 hectare (2.5 acres). Estimates of habitat characteristics over large spatial extents often reveal different patterns than those derived from smaller spatial extents. Neither estimate is incorrect. Instead, patterns revealed at different extents are complementary and informative for multi-scale planning.

Grain is the resolution at which spatial patterns are measured (Figure 3). Resolution of spatial data affects how well the true conditions are estimated for a given size and type of mapping unit. Typical mapping units consist of pixels or polygons. Pixels are a grid of cells, such as squares or hexagons, into which the spatial extent is subdivided. By contrast, polygons consist of vector boundaries of irregular shapes that subdivide the analysis area. Spatial grain is influenced strongly by the minimum size of pixels or polygons used to estimate habitat characteristics. For example, the resolution associated with a 30-m pixel is substantially higher than that associated with a 1000-m pixel, with estimates that are lower in bias (i.e., closer to the true value) and higher in precision (i.e., produce more consistent results).

Consequently, spatial grain affects the accuracy of estimates made over a specified spatial extent, with accuracy defined as the combination of bias and precision associated with spatial estimates for a given time and place. In spatial evaluations of accuracy, measures of bias often are referred to as classification accuracy; this form of accuracy is typically expressed as the percentage of times a spatial estimate correctly identifies the true attribute. For example, 70% classification accuracy might refer to the percentage of times that a particular type of sagebrush habitat was correctly mapped, given a specified spatial grain and extent.

The map pixels of Figure 3 illustrate the differences in accuracy of habitat estimates resulting from differences in spatial grain. For a given spatial extent, the coarser the grain, the lower the accuracy. For example, although the spatial extent covered by the coarse pixel is dominated by Habitat 3, it contains appreciable area of Habitats 1 and 2. The coarse pixel is classified, however, as only one habitat type (Habitat 3), owing to Habitat 3 being the dominant type. In this instance, appreciable amounts of Habitats 1 and 2 are not classified because of the coarse spatial grain and therefore are not included in the estimate, representing a reduction in accuracy. By contrast, if one were to use fine-grained pixels to classify the same sized area as the coarse pixel (compare habitats across the coarse, moderate, and fine pixels in Figure 3), the fine pixels would classify the area as a combination of Habitats 1, 2, and 3, with Habitat 3 as most abundant, and Habitat 1 as least abundant. The result would a more accurate portrayal of the habitat types within that spatial extent of interest.

Hann et al. (1997) and Wisdom et al. (2000) summarized the accuracy of regional assessments based on spatial data estimated at coarse resolution (1-km^2 pixels) in the Interior Columbia Basin. They found that vegetation data were of acceptable accuracy to meet assessment goals when summarized at the largest spatial extents, such as the basin (58 million hectares, or 144 million acres), ecological province (>1 million hectares), or subbasin (>300,000 hectares, or >740,000 acres). By contrast, vegetation data estimated for smaller spatial extents, such as for a watershed (20,000 hectares, or 50,000 acres) or subwatershed (8,000 hectares, or 19,000 acres), were not sufficiently accurate unless data were summarized for large groups of watersheds or subwatersheds.

Specifying temporal scale also is vital in regional assessments; that is, whether past or future changes will be considered, over what time periods such changes will be estimated (temporal extent), and how different methods of estimating conditions at different time periods will be reconciled (Noon and Dale 2002). Different methods used to obtain habitat estimates for

each time period affect the spatial grain and accuracy at each point in time, in turn affecting the estimates of habitat change over time. As with spatial scale, the objectives of a temporal analysis determine the extent and accuracy of habitat estimates that are required.

ANALYTICAL STEPS TO MEET OBJECTIVES

Suggested Procedures for Spatial Analysis in Sagebrush Ecoregions

The following steps are intended for application at large spatial extents, such as ecoregions, as well as ecological provinces, subbasins, or other large areas (≥100,000 hectares) nested within each ecoregion (Figure 3). We consider these steps to be the minimal procedures needed to conduct a regional assessment for a comprehensive set of species of conservation concern. As such, these steps are a starting point, to which many complementary analyses can be added. For example, analyses of habitat fragmentation, connectivity, or patch size (Knick and Rotenberry 2002) can be completed after mapping species-habitat threats and risks, and the results used in change detection research. That is, fragmentation, connectivity, and patch size of sagebrush habitats could be measured and mapped before and after the projected loss of habitat that may result from various threats. Such analyses could be completed for individual species or groups of species, based on differences in species' responses to patterns of habitat loss. Examples of such complementary analyses are described later (see *Other Procedures for Spatial and Temporal Analysis*).

Our analytical steps are not necessarily linear; that is, the numbered steps need not be completed in sequence. For example, the first step, *Identify Species of Conservation Concern*, requires knowledge of species ranges, which is part of step 2, *Delineate Species Ranges*. Step 1 requires simple knowledge of whether the range of a given species in the ecoregion is large enough (≥100,000 hectares) for the species to be included in the regional assessment. By contrast, step 2 requires delineation of the specific boundaries of occurrence, so that habitats for each species can be assessed within its respective range. Accordingly, the chronology and details of the following steps can be modified and adapted to meet the specific needs of a given regional assessment.

1. Identify the Ecoregion and Associated Spatial Extents—Ecoregions within the sagebrush ecosystem have been identified and mapped by TNC (Figure 1). These ecoregions, and the amount of sagebrush in each, are listed in Table 1. The reasons for selecting a given ecoregion for regional assessment can be varied and complex, and should be stated clearly. Reasons might include concerns about habitat loss from specific threats, such as energy development (Braun et al. 2002, Noss and Wuerthner 2002). Alternatively, interest in the status of habitats for high-profile species, such as pygmy rabbit (*Brachylagus idahoensis*) or sage-grouse, may drive the selection of an ecoregion. Moreover, knowledge of habitat conditions for such high-profile species in relation to those for a larger set of sagebrush-associated species may be of keen interest in selecting an ecoregion.

Once the ecoregion is chosen, the associated spatial extents of interest can be identified for further assessment. For example, ecoregions follow ecological boundaries, but management typically follows administrative boundaries, such as those of State and Field Offices of the BLM (Figure 4). Consequently, results can also be assessed for these large administrative extents that

are nested within an ecoregion, or that overlap largely with ecoregion boundaries. Accordingly, Wisdom et al. (2003) assessed sagebrush habitats for the Great Basin Ecoregion, but also summarized results statewide for Nevada, and for BLM Field Offices within Nevada.

Assessments can include other spatial extents beyond ecological and administrative boundaries. Hydrologic extents, such as watersheds or subbasins, often are used for management planning. The Great Basin Restoration Initiative, for example, focuses on restoration planning by watershed within the Initiative's boundaries, which encompass large portions of the Great Basin and Columbia Plateau Ecoregions (USDI Bureau of Land Management 1999). See Step 9, *Summarize Results for Species and Groups at Desired Spatial Extents*, for additional details about summarizing results for regional assessments at a variety of large spatial extents.

2. Identify Species of Conservation Concern for Assessment in the Ecoregion—A comprehensive list of species of conservation concern in the sagebrush ecosystem was recently compiled by Suring et al. (in prep., Appendix 2). This master list can be used to identify the species of conservation concern for regional assessment in a given sagebrush ecoregion. Identification of these species involves a multi-step screening process (Figure 6). The initial steps are (1) consult the master list of species of conservation concern that exist in the sagebrush ecosystem (Appendix 2); (2) identify those species on the master list that occur within the ecoregion of interest; and (3) identify the species from step 2 that are ranked S1, S2, S3, or S4 by NatureServe (NatureServe 2001) for any state in the ecoregion.

Species with rankings of S1, S2, S3, or S4 are screened further by determining whether their ranges are $\geq$100,000 hectares (step 4, Figure 6). Any species whose range in the ecoregion is <100,000 hectares is dropped, owing to uncertainties about the accuracy of mapping the small areas occupied by such species (Figures 3, 7). Range maps are available (e.g., Opler et al. 1995, Wilson and Ruff 1999) to estimate whether range size is sufficient to include each species of concern in the regional assessment. (See the following section, *Delineate Species Ranges,* for definitions and procedures for mapping a species' range.) Importantly, the availability of more accurate spatial data in the future will allow habitats for species with smaller ranges to be mapped adequately in relation to goals and objectives of a regional assessment.

The remaining species are then evaluated as to whether they are associated with macro-habitats that can be accurately mapped with coarse spatial data (e.g., Comer et al. 2002) currently used for ecoregion assessments (step 5). Species associated with micro-habitats, which cannot be mapped accurately with coarse spatial data, are dropped. (See Appendix 1 for definitions of macro- versus micro-habitats.)

Species associations with macro- versus micro-habitats can be evaluated by researching the species' life history and associated habitat requirements: if habitats for the species can be mapped at coarse resolution, such as that provided by the 90-m sagestitch map (Comer et al. 2002), and summarized over large spatial extents, the species is suitable for regional assessment (step 5, Figure 6). Species that respond primarily to micro-habitats must be evaluated at local scales, and are not suitable for regional assessment (step 5). For example, the availability of local roost sites, a critical requirement for many species of bats, cannot be detected or mapped at regional scales. Similarly, many species are local endemics, requiring knowledge of site-specific conditions in relatively small areas. Habitats for such species must be assessed at local scales that allow accurate mapping of these fine-scale features.

A final step in identification of species of concern is to consult sources beyond those considered by Suring et al. (in prep., Appendix 2), to determine whether additional species can

be considered for ecoregion assessment (step 6, Figure 6). Examples of such lists include conservation targets identified by TNC for conservation planning within ecoregions (e.g., Nachlinger et al. 2001), and species identified as sensitive or having other designations of special status by state agencies in the ecoregion.

The final step is for species experts to review and refine the list (step 7, Figure 6). This review can ensure that all species of concern are identified, that species are correctly targeted for regional versus local assessment, and that existing knowledge about habitats and populations of each species is summarized correctly and sufficiently as part of the assessment.

3. Delineate Species Ranges—Knowledge of the range of each species is needed because differences among ranges for many species can result in differences in habitat status and response to management. We define a species' range as the polygon or polygons that encompass the outer boundaries of a species' geographic occurrence within an ecoregion. A species' range can consist of one or more polygons, with each polygon encompassing an interacting population (Figure 7). Species with ranges composed of two or more polygons are assumed to have disjunct populations (Figure 7), with little or no interaction of populations across polygons.

Importantly, our definition of a species' range says nothing about the spatial structure of the population inside each polygon, except to assume that one interacting population exists. This definition contrasts strongly with distribution maps of populations, often generated from documented occurrences of a species. Our definition also differs strongly from maps of predicted distribution of habitats for species, such as those produced by GAP analysis (Scott et al. 1993).

Four example ranges are shown in Figure 7: (1) large, interacting; (2) large, disjunct; (3) small, isolated; and (4) small, fragmented. For broadly-distributed species with one interacting population, the range is depicted as one large polygon that encompasses areas of both used and unused habitats. For common species with disjunct populations, range maps reflect the outer extent of individual populations, and the ranges consist of two or more separate polygons, representing two or more separate populations that have little or no interaction (Figure 7). Locally endemic species or species with small, scattered populations can have ranges expressed as one small polygon (one small, isolated population) or a series of small populations (a set of small, fragmented populations) (Figure 7).

Delineation of each species' range in a regional assessment is a key step because of the above-mentioned spatial differences in habitat conditions, and response to management, that can result from non-overlapping portions of ranges. For example, the range of sage grouse has contracted substantially since historical times (Figure 2); this reduced range contrasts strongly with other sagebrush-associated species, such as the sage sparrow (*Amphispiza belli*) and sagebrush vole (*Lemmiscus curtatus*), whose ranges extend over a larger area of the sagebrush ecosystem (Carroll and Genoways 1980, Martin and Carlson 1998). Consequently, results of a regional assessment for these 3 species could vary substantially, thus complicating short-cut management approaches like "umbrella species," as proposed for sage grouse (e.g., Rich and Altman 2001). (See Appendix 5, "*Short-cut Approaches to Multi-species Assessment.*")

For most species included in a regional assessment, published range maps are available and typically can be used for assessment without modification. Range maps for birds are included in species accounts of The Birds of North America series (Birds of North America, Inc., www.birdsofna.org). Range maps for mammals include those provided by Hall (1981), Zeveloff (1988), Wilson and Ruff (1999), and mammalian species accounts (American Society of

Mammalogists, www.science.smith.edu/departments/Biology/VHAYSSEN/msi/default.html). Stebbins (1985) includes range maps for reptiles and amphibians of the western United States. Ranges of plants and invertebrates are available from many local sources, such as Albee et al. (1988), Morefield (2001), Opler et al. (1995), and Utah Division of Wildlife Resources (2002).

Range maps can be digitized and clipped to the boundaries of the ecoregion under assessment. Habitat assessment for a given species is then conducted within the boundaries of the species' range, as nested within the ecoregion or smaller spatial extents inside the ecoregion.

4. Estimate Species Habitat Requirements—A critical part of any multi-species assessment is to identify the habitats on which each species depends. For this purpose, we define habitat in a specific way, referred to as "source habitats." Wisdom et al. (2000, vol. 1:4-5) defined source habitats specifically for the purpose of regional assessments:

"Source habitats are those characteristics of macro-vegetation that contribute to stationary or increasing rates of population growth for a species in a specified area and time. Source habitats contribute to source environments (Pulliam 1988, Pulliam and Danielson 1991), which represent the composite of all environmental conditions that result in stationary or increasing rates of population growth for a species in a specified area and time. The distinction between source habitats and source environments is important for understanding a regional habitat evaluation and its limitations. For example, source habitats for a bird species during the breeding season would include those characteristics of macro-vegetation that contribute to successful nesting and rearing of young, but would not include non-vegetative factors, such as the effects of pesticides on thinning of eggshells, which also affect production of young.

Consideration of both vegetative and non-vegetative factors that contribute to population persistence requires an evaluation of source environments, which is beyond the purpose and scope of most regional assessments of habitat. As part of the process of identifying and evaluating vegetation characteristics that contribute to stationary or increasing population growth, however, we defined and identified source habitats as being distinctly different from habitats that are simply associated with species occurrence, which may or may not contribute to viable, long-term population persistence. That is, in contrast to source habitats, those habitats in which species occur can contribute to either source or sink environments (Pulliam and Danielson 1991). Consequently, species occurrence by itself indicates little or nothing about the capability of the associated environment to support long-term persistence of populations (Conroy and Noon 1996, Conroy et al. 1995). Consequently, data based strictly on species occurrence does not meet objectives to identify those characteristics of macro-vegetation that support long-term population persistence, which we defined as source habitats."

For regional assessment of sagebrush-associated species, source habitats can be considered, at a minimum, to be the cover types on which each species depends or is thought to depend. This is in contrast to more typical designations of species-habitat association, in which habitats listed are those in which the species is predicted to occur (e.g., Scott et al. 1993). Such designations reveal little about whether the habitat is a "source" or a "sink," as discussed above.

Every species is affected to some degree by non-vegetative factors, and such factors also can be addressed in a regional assessment. For example, Raphael et al. (2001) identified three habitat and two non-habitat factors affecting Greater sage-grouse in their regional assessment:

habitat quantity, as measured by the area of sagebrush cover types; two indices of habitat quality, indicating the degree to which native grasses and forbs in the understory of sagebrush were present, degraded, or absent; and two indices of human disturbance effects on populations.

Identifying each species' requirements in relation to the classification system of vegetation used for mapping, or to other spatial layers of non-vegetative factors that index a species' requirements, is an important part of a regional assessment. At a minimum, the cover types that function as source habitats need to be identified, along with supporting rationale. As an example, the 57 land cover types classified in the 90-m sagestitch map can be used to designate source habitats for each sagebrush-associated species (Table 3), using the following process. First, identify the vegetation coverage to be used, in this case the 90-m sagestitch map. Second, associate each species with the cover types known or considered to be source habitats, based on literature review and an evaluation by species experts with specialized knowledge of each taxon (e.g., birds). Example habitat associations are shown for sage grouse and loggerhead shrike (*Lanius ludovicianus*; Table 3). Last, identify other habitat and non-habitat factors beyond source habitats that also could affect species' persistence, such as population size or presence of roads (e.g., Lee 2000, Marcot et al. 2001). Identification of these additional factors will allow regional assessments to be more comprehensive in evaluating conditions for individual species of concern.

5. Identify Regional Threats and Potential Effects—Identification of regional threats and their potential effects is perhaps the most fundamental and essential component of any regional assessment for species of conservation concern. A plethora of threats to the sagebrush ecosystem and its associated species have been identified (Table 4); this list can be used as a starting point to identify and evaluate threats in a regional assessment. The importance of these threats in any particular sagebrush ecoregion will vary, depending on local environments, both ecological and political. For example, loss of sagebrush from cheatgrass invasion is a major threat for the Great Basin and Columbia Plateau Ecoregions (e.g., Nachlinger et al. 2001). By contrast, energy development is a more pervasive threat in the Wyoming Basins Ecoregion (e.g., see USDI Bureau of Land Management 2001*a*, Braun et al. 2002). In addition, the significance of various threats to the sagebrush ecosystem has changed over time: some issues, such as large-scale conversion of sagebrush to cropland, have diminished, while others, such as invasion of exotic species, have expanded.

Beyond a simple list of threats, risk assessment involves "obtaining quantitative or qualitative measures of risk levels" (Burgman et al. 1993:13). Estimating risks to habitats for species of concern is essential to informed decision-making. Without such estimates, management decisions may be based on unrealistic perceptions of risk. Risks that are less amenable to control often are perceived to be less important than those that can be addressed easily (Burgman et al. 1993).

Results from risk assessment provide information that decision-makers can use to allocate limited resources for species conservation and management. For example, one could estimate the risk of invasion by pinyon-juniper woodlands into sagebrush based on elevation, precipitation, taxon of sagebrush, proximity to pinyon-juniper, and other factors (Figure 8). Sagebrush sites at high risk of invasion could be targeted for removal of nearby pinyon and juniper (Wisdom et al. 2003). In addition, mapping sagebrush stands by risk would allow managers to identify areas where less attention is currently warranted, as well as areas where immediate action is needed to reduce the risk of woodland invasion. An example of mapping

this threat is provided in our prototype assessment (Wisdom et al. 2003), and illustrated in Figure 8. Importantly, the spatial and temporal scales of management treatments must be evaluated to ensure their effectiveness to reduce risk over time and space in relation to management objectives.

Threats to a species' persistence in the sagebrush ecosystem can be broadly categorized as environmental (indirect) or population (direct) (Figure 9). Environmental effects pose indirect threats to populations by first degrading the environment on which the species depends, which in turn affects population characteristics (Figure 9). Environmental effects often are amenable to management, are primarily deterministic, and include such changes as habitat loss, habitat degradation, or environmental contamination (Andelman et al. 2001). Population effects often are stochastic, and come into play when small population sizes occur in response to some combination of direct and indirect threats. Population effects and the resulting problems include genetic considerations, such as inbreeding depression, and demographic effects, such as Allee effects (Figure 9; Andelman et al. 2001). Ultimately, managers are concerned about all threats to population persistence, which can increase the likelihood of population extirpation, or even the extinction of a species (Figure 9).

Efforts to classify threats according to their potential effects (e.g., whether the threats affect populations directly, indirectly through the environment, or both; Table 4 and Figure 9) are confounded by the synergism of many threats, as well as the multiple ways in which single threats may be expressed in the system. For example, excessive or inappropriate livestock grazing can simultaneously reduce the quality of habitat for foraging by, and increase predation pressure on, Greater sage-grouse. Overgrazing leads to 1) removal of perennial grasses and forbs that support insects and other prey items, and 2) the loss of forbs that serve as key forage items in the spring (environmental effect of habitat degradation; DeLong 1993, Gregg et al. 1994). Removal of grasses may also increase predation rates on nests by decreasing nesting cover (a second example of habitat degradation; Gregg et al. 1994, DeLong et al. 1995).

Decisions about which threats to address in a particular assessment area can be based on any of several criteria, including:

- Spatial extent or pervasiveness of the threat across the ecoregion;
- Capability to quantify and map the threat;
- Agreement among those conducting the assessment about the relative importance of the threat to sagebrush habitats in the ecoregion;
- Public opinion about the threat;
- Available resources to address the threat;
- Timeframe required to implement effective treatments across the ecoregion;
- Costs versus benefits of addressing the threat; and
- Potential effects of addressing the threats on non-target species.

Any combination of these criteria can be used to identify the dominant, regional threats for a given ecoregion. Obviously, the more criteria considered, the better the justification for conducting a regional evaluation of threats. Identification of regional threats and their potential effects on species of concern can draw substantially on knowledge from rangeland management specialists, wildlife biologists, endangered species specialists, and other resource professionals working in the assessment area, along with published literature. At a minimum, the list of dominant threats and potential effects can be reviewed and refined by local and regional experts to derive a list like that shown in Table 4, customized for the ecoregion.

6. Estimate and Map the Risks Posed by each Threat—Once the regional threats are identified and their potential effects described, the risks posed by each threat can be estimated and mapped to evaluate the spatial effects on habitats for species of concern. While Table 4 can be used as a master list to identify the regional threats that may be pertinent, and to describe their general effects, specific risks may be difficult to quantify (Burgman et al. 1993). Consequently, we suggest the following process be used. First, define the risk levels posed by the threat. Risk levels can be expressed as probabilities, from 0.0 to 1.0, which estimate the likelihood that habitats will be lost or degraded over a specified period of time, based on the threat. Alternatively, risk levels can be defined as categories, such as high, moderate, and low, with explicit descriptions of the meaning and interpretations of each category. For example, levels of risk that sagebrush will be displaced by cheatgrass were defined by Wisdom et al. (2003) for the Great Basin Ecoregion (Table 5). Note that these definitions identify levels of risk, as well as the time period over which the associated habitat loss may occur.

Second, develop a spatial rule set for mapping each risk level in a geographic information system (GIS); in the case of cheatgrass displacement of sagebrush in the Great Basin, a rule set based on elevation, aspect, slope, and landform was used (Wisdom et al. 2003). Third, summarize the amount of sagebrush area by risk level; for example, the area of sagebrush at low, moderate, and high risk of displacement by cheatgrass (Figure 10). And fourth, interpret and describe the potential implications of the results for management, particularly in relation to time, area, and resources needed to mitigate various risk levels. Example interpretations and implications for the threat posed by cheatgrass are shown in Table 6.

As part of this process, it is important to identify ecological thresholds, if any, in relation to levels of risk. For example, areas of sagebrush at moderate risk to displacement by cheatgrass are considered to be slightly above the threshold for displacement; once the threshold is crossed, conversion to cheatgrass may be permanent (Wisdom et al. 2003). By contrast, areas of sagebrush at low risk are considered to be well above this threshold, while areas at high risk have likely passed through the conversion threshold (Table 6; Wisdom et al. 2003). These patterns suggest that resources available for reducing the risk of cheatgrass displacement are best directed toward mitigating the threat to areas at moderate risk.

The two case examples described above for risks posed by pinyon-juniper and cheatgrass (Figures 8, 10) illustrate the results of estimating and mapping the dominant, regional threats to sagebrush across an ecoregion. In addition, we provide two conceptual examples for estimating and mapping risks to sagebrush habitats from powerlines (Figure 11) and from energy development (Figure 12). Each process is spatially explicit, based on rules that define conditions or zones where effects vary by risk level.

To evaluate effects of powerlines, levels of risk are based on home range size of large, avian predators (shown as oblong circles) that would benefit from the use of powerline structures

as nesting platforms and hunting perches, which, in turn, would result in higher predation rates on species of concern that are prey (Figure 11). In this example, habitats within the central core of the predator's home range, when the center is placed along the powerline, are defined as being at high risk of being unsuitable, owing to high rates of avian predation on species of concern. Habitats outside the central core, but inside the home range, are characterized as moderate risk. Habitats outside the home range are defined as low risk.

Critical assumptions for estimating such risks include: size and shape of the home range of selected avian predators; placement of the home range in relation to the powerline; degree to which predation rate within the home range varies by distance from the core of the home range; the species of conservation concern that would be preyed upon by the avian predators; and the distribution of the prey species in relation to the powerline. Species experts can review and refine these assumptions, and provide supporting empirical rationale and evidence for the approach taken.

To evaluate effects of energy development, levels of risk are based on the distance of each pixel of habitat to the nearest development, defined as the energy site itself and the associated network of roads, which compose the development boundaries (Figure 12). Pixels of habitat within the development boundaries are classified as being at high risk of being lost or degraded to point of being unsuitable for species of concern. This high risk is due to habitat conversion to energy sites and roads, to habitat fragmentation, to facilitation of exotic plant invasions, and other human-associated factors of disturbance described by Braun (2002), Noon (2002), and Noss and Wuerthner (2002).

In the example shown in Figure 12, pixels outside the development boundaries, but within specified distances from the boundaries, are defined as moderate or low risk of being lost or degraded to the point of being unsuitable. These distance estimates would vary by the species being evaluated, according to differences in home range, dispersal characteristics, and the species' response to habitat fragmentation and disturbance. Methods for estimating such risks include (1) defining and mapping the development boundaries; and (2) estimating the degree to which habitat becomes non-functional by distance from site and by species.

Estimation of spatially pervasive threats can be used as the foundation for more specific evaluations of habitat conditions and threats for single and multiple species of concern, as applied to individual species ranges, as well as to the collective range of all species. Our prototype assessment for the Great Basin provides further examples of how threats and associated risks can be evaluated for individual species and for groups of species (Wisdom et al. 2003).

*7. **Calculate Species-Habitat Effects from Risks of all Threats***—The process of identifying regional threats and associated risks can be used to map and calculate the current amount of habitat for each species, within its range, by the type of threat and the risk levels posed by each threat. This process involves the following steps:

(1) For a given species, sum the number of 90-m pixels that are source habitats for the species, and calculate the area (hectares or acres) occupied by these habitats; and

(2) For a given threat, overlay the risk levels of habitat loss or degradation associated with each pixel of the species' source habitats; then sum the number of 90-m pixels at high, moderate, low, and no risk of habitat loss or degradation for the species, and

calculate the area (hectares or acres) of source habitats associated with each of these risk levels.

This analysis is straightforward when addressing a single threat, as illustrated for Greater sage-grouse and sagebrush vole in the Great Basin Ecoregion (Figure 13). The process becomes more complex, however, when multiple threats and associated risks are considered. In this case, the combination of multiple threats to a species' habitat may be difficult to summarize, owing to complexities of many categories of combined risks, the potential interactions among threats, and the more difficult interpretations for management. For example, three levels of risk from cheatgrass invasion and three levels from pinyon-juniper invasion combine to form nine categories of collective risk to sagebrush habitats (Wisdom et al. 2003).

Managing for different levels of risk from multiple threats requires substantial experience, collective judgment, and supporting rationale. In the case of the combined risks of sagebrush displacement by cheatgrass and pinyon-juniper, the following management implications are noteworthy: (1) areas at high risk of displacement by cheatgrass, but also at high risk of displacement by pinyon-juniper, may be difficult or impossible to maintain as sagebrush habitats, considering the management challenges posed by the combined risks; (2) areas at low risk of displacement by both cheatgrass and pinyon-juniper are most resilient to disturbance regimes of fire, grazing, and recreation; these areas therefore have a high probability of responding in a positive or neutral manner to a variety of management activities, excluding land use changes that eliminate habitat through conversion to urban, agricultural, mining, or energy development; and (3) areas at moderate risk to both cheatgrass and pinyon-juniper displacement are likely to be sensitive to fire, grazing, and other land management disturbances; that is, such disturbances in these areas may increase the vulnerability of sagebrush habitats to invasion and displacement by cheatgrass and pinyon-juniper. Consequently, areas at moderate risk may demand the most management attention, and are likely to respond positively to appropriate improvements (Wisdom et al. 2003).

With these points in mind, the process of calculating habitat area for a given species can be done in a variety of ways in relation to the combination of threats to the species' habitats. The most appropriate process is one that is both ecologically sound and has the most straightforward management implications, particularly in relation to prevention of threshold effects. That is, an appropriate summary of habitat area in relation to multiple threats would be a summary that portrays the various combinations of habitat threats in a manner that allows managers to design practices that prevent thresholds from being crossed, from which restoration of habitats may be impractical or infeasible.

The following guidelines can aid decisions about how best to combine and map different levels of risks from multiple threats for species' habitats:

- Describe the potential cumulative effects of risk from multiple threats in a clear and defensible manner.

- Identify the most severe and the most benign of the potential effects from the multiple threats, to illustrate the range of possible effects. Contrast these extremes with moderate levels of combined risk to illustrate more plausible effects.

- Describe potential synergies among multiple threats, and explain how these synergies might be reduced or avoided with appropriate management.

- Develop a clinical list of all mitigating actions, their effectiveness, and their costs. Describe trade-offs of resource inputs needed to mitigate the combined risks, versus the benefits of achieving the mitigation.

- Identify species and associated habitats that may be at greatest risk from the multiple threats. Refine the mitigating actions and trade-off analyses based on consideration of these species and their habitats.

8. Form Species Groups to Generalize Results Across Species—Regional assessment of vast areas such as an ecoregion typically calls for evaluation of 50 or more species of conservation concern (e.g., Wisdom et al. 2000), and can include hundreds or even thousands of species altogether (e.g., Thomas et al. 1993*a*, 1993*b*, Marcot et al. 1998, Nachlinger et al. 2001; Appendix 3). For land managers, individual attention to 50 or more species can be impractical. To address these inefficiencies, various "shortcut" methods have been proposed to eliminate or reduce the number of individual species that are explicitly considered in an assessment and in subsequent management. Among the more popular shortcuts are (1) umbrella species; (2) surrogate species; (3) focal species; (4) landscape indicators; and (5) species groups (see Appendix 5 for detailed descriptions of these and other approaches).

In contrast to shortcut methods that use single species or landscape indicators, the use of species groups, as defined by Wisdom et al. (2000), is an explicit attempt to address the needs of both single and multiple species in a hierarchical fashion (Figure 14). In the most optimistic sense, use of species groups, in combination with individual species, may enable managers to (1) address either single- or multi-species needs, depending on objectives; (2) identify regional habitat patterns that affect multiple species similarly; (3) address the needs of many species efficiently and holistically with the use of regional strategies for the groups; (4) determine how well the regional strategies for groups of species meet the needs of individual species within the groups; and (5) summarize results for species and groups at multiple spatial extents to maximize flexibility in the design and implementation of regional strategies. In the most pessimistic sense, use of species groups may not reflect robust patterns among species, may fail to account for key requirements of individual species, and may provide a false sense of confidence for managers unwilling to consider the unique needs of individual species.

Consequently, we recommend the use of species groups in regional assessments in the sagebrush ecosystem, but with the caveat that assumptions about how well the species groups represent the needs of all individual species of concern be tested as part of management implementation in partnership with research (Appendix 5). Depending on objectives, species can be grouped by various criteria, such as commonality among habitat associations, life-history traits, or threats to persistence (Wisdom et al. 2001, Appendix 5). Using the conceptual approach in Figure 14, each species is placed in one of five example groups (Figure 15), based on the degree to which the species is associated with sagebrush cover types (e.g., nearly exclusively, or more broadly with a combination of sagebrush and other cover types).

Placing species in the five example groups (Figure 15) can be accomplished in several ways, ranging from simple rule sets to formal analyses such as hierarchical cluster analysis (Wisdom et al. 2000, 2001). The following process is one means of placing species in the five

example groups, based on a simple rule set to establish the initial groups and cluster analysis to finalize the groups. The rules are based on the degree of a species' dependence on sagebrush versus non-sagebrush cover types. For example, if >75% of the cover types identified as source habitats for a species are sagebrush types, the species is considered a "sagebrush obligate" (Figure 15). By contrast, if 25-75% of the source habitats for the species are sagebrush types, and the remainder dominated by salt desert scrub, by woodlands, or by grasslands, the species is placed in the appropriate group: sagebrush-arid shrubland, sagebrush-woodland, or sagebrush-grassland (Figure 15). Species not placed using the above rules fall into the category of "sagebrush generalists." An alternative rule set is one based on the amount of each cover type used as source habitat by each species in the analysis area, rather than on the number of cover types. For example, if 80% of a species' source habitats are in sagebrush cover types, and 20% in salt desert scrub, but the actual habitat present for the species in the ecoregion is 10% sagebrush and 90% salt desert scrub, it may be difficult to justify placing the species in the sagebrush obligate group. Instead, the species may fit more appropriately in the sagebrush-arid shrubland group (Figure 15).

Cluster analysis can provide further insight about similarities in habitat associations among the species (SAS Institute, Inc., 1989, Wisdom et al. 2000). Hierarchical cluster analysis allows examination of how each species is joined into groups based on similarities with other species' habitats. Each species constitutes a "group" at one end of a hierarchical tree, until all species are joined together to form 1 inclusive group at the other end. Alternatively, the number of desired groups can be specified. Species membership in each group, while varying the numbers of groups, can be examined in relation to knowledge of similarities among species' habitats. A statistician or quantitative ecologist is best qualified to conduct the cluster analysis and can assist in interpreting its meaning.

Results of the cluster analysis can be used to adjust membership of species in the groups, and to adjust the number of groups. Species membership in the modified groups can be reviewed by species experts, along with supporting rationale for why species were placed in each group. This process can iterate many times until agreement is reached about the appropriate membership of species in the groups, and about the desired number of groups needed to meet objectives.

In general, land managers want to minimize the number of groups to be dealt with in land use decisions, but ecologists are likewise reluctant to include too many diverse species in the same group. One solution is to establish multiple levels of grouping for regional assessment, ranging from evaluation of individual species, to groups of species, and to "families of groups" (Figure 14; Wisdom et al. 2000). In this way, managers can use results for the "families of groups" to establish regional habitat strategies, and ecologists can check the efficacy of the approach for individual species and groups of species within each "family" (Wisdom et al. 2000).

9. Summarize Results for Species and Groups at Desired Spatial Extents—Results of regional assessments can be summarized across all sagebrush ecoregions, for each sagebrush ecoregion, and for a variety of large spatial extents (areas $\geq$100,000 hectares) within each ecoregion (Figure 3). Spatial extents within an ecoregion can include hydrological, ecological, and administrative boundaries (Figure 4).

Example hydrological extents include watersheds (5th hydrologic unit codes, with a mean area $\geq$100,000 hectares for multiple watersheds) or subbasins (4th hydrologic unit codes, with a

mean area of approximately 300,000 hectares per subbasin). Ecological extents include ecological provinces, such as the 14 provinces established by West et al. (1998) and Miller et al. (1999) in the Columbia Plateau and Great Basin Ecoregions (mean area of approximately 5 million hectares [15 million acres] per province), or the 13 Ecological Reporting Units developed by Hann et al. (1997) for the Interior Columbia Basin (mean area of approximately 2.4 million hectares [5.9 million acres] per Reporting Unit). The Nature Conservancy's portfolio sites for conservation (Groves et al. 2000, Nachlinger et al. 2001) are another example of useful ecological extents at which results of regional assessments can be summarized.

Other ecological extents might include a moving window analysis (see Glossary) based on varying sizes of home ranges for the species of concern. For example, two moving windows could be established, one based on home range sizes typical of wide-ranging species, such as sage grouse, and another based on home ranges typical of species with smaller area requirements, such as sagebrush vole.

Administrative extents include the national level, encompassing all areas of BLM and FS ownership across all sagebrush ecoregions, as well as intermediate and finer administrative extents, ranging from BLM State Offices or FS Regional Offices to field units of both agencies (Figure 4). Findings summarized to administrative extents can be crudely cross-referenced to summaries made at hydrological and ecological extents, and vice versa; this can be accomplished by selecting administrative, hydrological, and ecological extents that are similar in size and boundaries. Note, however, that different results should be expected from results summarized for different types of spatial extents, owing to differences in size and boundaries.

Summarizing results for individual species and for species groups at the desired spatial extents is one of the final steps in a regional assessment. Wisdom et al. (2002*d*) summarized habitat conditions for groups of species for each watershed in the Interior Columbia Basin (Figure 16). Each watershed was characterized as one of three conditions for each species group. Watersheds in Condition 1 contained habitats that have undergone little change in quality or abundance since the historical period. By contrast, watersheds in Condition 2 or 3 contained habitats that have changed from historical conditions, but in different ways. Watersheds in Condition 2 had habitats of high abundance but moderate resiliency and quality. Watersheds in Condition 3 contained habitats of low abundance or low resiliency and quality, and contained large spatial gaps where habitat had been lost (Figure 16).

This map of habitat conditions for groups of species is referred to as a "habitat network" (Wisdom et al. 2002*d*). This network, or mosaic, of habitat conditions for each species group appears to have high utility for regional planning (USDA Forest Service and USDI Bureau of Land Management 2000). For example, information about the network could be used by managers as guidance to maintain habitats in a relatively unchanged state from historical conditions (Condition 1), to improve habitats where quality and resiliency have declined (Conditions 2 and 3), to restore habitats in areas of extirpation or low abundance (Condition 3), and to improve connectivity where spatial gaps have developed (Condition 3). See Hobbs (2002) for a detailed discussion regarding the use of habitat networks for conservation planning.

A similar network could be characterized at desired spatial extents for groups of sagebrush-associated species within an ecoregion. For example, for a given species group, each watershed in an ecoregion could be characterized as one of four conditions: (1) habitats are of high abundance and generally at low risk of being lost to regional threats; (2) habitats are of high abundance but mostly at moderate or high risk of being lost; (3) habitats are of low or moderate abundance and mostly at moderate or high risk of being lost; and (4) habitats are of low or

moderate abundance but generally at low risk of being lost. Watersheds in Condition 1 may require little or no management change. By contrast, watersheds in Conditions 2 and 3 may require careful management attention to reduce the risks of habitat loss. Moreover, watersheds in Conditions 3 and 4 may need attention in terms of increasing the abundance of habitats. Regional strategies could be developed for watersheds in each condition to identify the appropriate conservation and restoration prescriptions needed to meet management goals for the species group. In turn, spatial priorities for allocating limited resources for conservation and restoration could be mapped for each watershed based on the conditions.

10. List Major Assumptions, Limitations, and Guidelines for Management—Regional assessments have sometimes been criticized as being too coarse to reflect ecological patterns and processes that affect species of conservation concern, and consequently, as having little management utility. While particular criticisms are warranted for any assessment, regional or local, criticisms of regional assessments as being "too coarse" often lack context regarding the objectives the assessment is intended to serve. For example, results from regional assessments may not be too coarse to meet evaluation objectives for large spatial extents such as an ecoregion or ecological province. Alternatively, the same assessment data may indeed be too coarse for use in a local area <100,000 hectares in size, which often represents the area encompassed by local management projects.

These points suggest that all assessments, regardless of scale, require an explicit listing of assumptions and limitations for appropriate management use as a fundamental step in the process. The following assumptions, limitations, and guidelines are likely to apply to management use of results from regional assessments of sagebrush habitats. Additional assumptions, limitations, and guidelines can be added to reflect the specific qualities of a given regional assessment for species of conservation concern.

- The primary audience for application of these procedures consists of spatial analysts, scientists, and resource specialists with strong backgrounds in landscape ecology, conservation biology, and spatial analysis. Resource managers and resource specialists without this expertise are not expected to fully understand all details of the document, nor are they expected to apply the procedures. That is, not all staffs at all levels of the agencies would be expected to apply the procedures. For example, this approach would be something that the BLM National Science and Technology Center in Denver or the USGS SAGEMAP Project in Boise would be expected to successfully apply. By contrast, an individual BLM District or Field Office may not have the resources and expertise to apply the procedures. However, such Districts and Field Offices would be expected to use the results of regional assessments as context for local land use planning.

- The cover types associated with each species, identified here as "source habitats," may not include all environmental conditions that determine whether a population is growing, declining, or stationary. For example, areas containing abundant source habitats may not support persistent populations of some species because of the negative effects of non-vegetative conditions, such as factors associated with roads; that is, source habitats may contribute to stationary or increasing population growth, but the road effect may override the habitat effect, thereby resulting in a sink environment. Knowledge about the negative

effects of non-vegetative factors (Figure 9) is therefore an important, complementary component to proper management of vegetation identified as source habitats.

- Estimates of habitat amount are based on the spatial extent of cover types, and these cover types are based on the dominant plant species present in the overstory of each pixel or polygon used for mapping. As such, these estimates do not reflect the quality of understory vegetation that may render some cover types unsuitable as habitat. For example, areas dominated by sagebrush may contain highly variable vegetation in the understory, ranging from the abundance of a variety of native grasses and forbs to complete dominance by exotic plants. Because the coarse pixel resolution used for regional assessments cannot map understory conditions, the amount of source habitats for some sagebrush-associated species may be overestimated. For example, sage grouse depend on an understory of native grasses and forbs for nesting and brood-rearing, and some areas identified as source habitats for this species may be unsuitable due to displacement of native understory plants by exotic grasses.

- Amount of source habitats and associated threats do not directly correlate with population effects. Loss of habitat projected from risks posed by various threats, however, is likely to be positively correlated with trends in populations of the associated species, but the degree of positive correlation is uncertain and likely varies by species and the effects of factors not accounted for in the regional assessment (Knick and Rotenberry 2002).

- Estimates of habitat amount with the use of coarse-pixel resolution, and subsequent estimates of habitat amount by levels of risk posed by threats, are of sufficient accuracy to meet regional assessment goals when results are summarized to spatial extents of the ecoregion, ecological province, subbasin, or other large areas generally 100,000 hectares (Hann et al. 1997; Wisdom et al. 2002; Figure 3). The 90-m sagestitch map should not be used to derive estimates for local areas. Exceptions to this rule may apply to particular analyses. In general, local analyses require data mapped at finer resolution than a 90-meter pixel. Such fine-resolution data are not available in continuous coverage format over large spatial extents, owing to exorbitant costs and processing demands associated with deriving such maps over millions of hectares.

- Habitat estimates are of lower accuracy for cover types that occur in small or linear patches, and often are substantially underestimated in relation to their true spatial extent. Consequently, linear features such as roads, narrow riparian strips, and smaller streams cannot always be mapped accurately at the 90-meter x 90-meter pixel size (0.81 hectare) used for the sagestitch map. Cover types that occur in small patches of <0.40 hectare (1 acre), for example, may not dominate a pixel, and thus not be mapped. Similarly, cover types that have an average patch size <1/4 the area of a 90-meter x 90-meter pixel (that is, <0.20 hectare [0.5 acres]) would not be mapped unless such cover types occur as multiple patches within the pixel. Cover types that occur as multiple patches within a pixel and that have an average patch size >1/4 the area of a 90-meter pixel (that is, >0.20 hectares), however, are typically mapped because some of these patches will be large enough to dominate the pixel. Importantly, many sagebrush cover types occur in patches that can

be mapped with a 90-meter pixel size at sufficient accuracy to meet most or all objectives of regional assessments.

- Knowledge of habitat requirements is better for commodity species (game or furbearer species) or threatened or endangered species (TE species, as listed under United States Endangered Species Act) than for species that have neither commodity nor TE status (Wisdom et al. 2002*d*). Knowledge also is better for birds than mammals and for mammals than reptiles and amphibians (Wisdom et al. 2002*d*). These varying levels of knowledge about species habitat requirements are indexed by like differences in the number of studies conducted on TE and commodity species versus species that are neither TE nor commodity, and on birds versus mammals versus reptiles and amphibians. Consequently, higher uncertainty is associated with habitat estimates for reptiles and amphibians than for birds or mammals, particularly birds and mammals that are TE or commodity species (Wisdom et al. 2002 d).

- Results for groups of species are intended for use in regional planning and management, allowing large numbers of species with similar habitat requirements to be managed efficiently. Each species occupies its own niche, however, and habitat estimates based on species groups do not always reflect conditions for individual species within a group. Consequently, any regional management strategy based on an assessment of species groups needs to be evaluated for its effect on individual species (Figure 15). The regional strategy can then be improved through a number of iterations of its development, in concert with checking its effect on individual species.

- Management use of the results for species groups is a coarse-filter approach that can be effective as regional context for local planning, analysis, and implementation. Coarse-filter management assumes that managing an appropriate amount and arrangement of all representative land areas and habitats will provide for the needs of all associated species (Appendix 5). Without such coarse-filter approaches for large spatial extents, the basis for management decisions at local scales may be unclear or could fail to consider the cumulative effects of past management on species of conservation concern. For example, an evaluation of sagebrush habitats for pygmy rabbit in a particular BLM Field Office may indicate that such habitats are abundant and at low risk from various threats. On the scale of the Field Office, this result might imply little need for special management. Results from the Ecoregion analysis may imply otherwise, however, suggesting a high risk of regional extirpation because of more widespread problems. In this case, special management of habitats within the Field Office may be important as part of a larger strategy to conserve and restore habitats for pygmy rabbit over a larger area beyond the boundaries of the Field Office.

- A major assumption of regional assessments is that research will be conducted to corroborate key patterns or processes that are mapped or modeled, and that may lack empirical certainty. That is, results from the regional assessment serve as regional hypotheses for testing and validation through large-area management experiments (Walters 1986). If validation research does not address the major sources of uncertainty associated with results of a regional assessment, the credibility of the assessment, and its

management uses, could be seriously questioned. Follow-on research to evaluate key knowledge gaps is a required part of regional assessments.

- Another major assumption is that results of regional assessments will be considered in tandem with finer-scale evaluations of habitats as part of local management. Results from regional assessments provide regional context for designing local conservation and restoration practices. Likewise, the effectiveness of addressing regional threats and regional habitat problems depends on effectively addressing these problems through local management plans. Ultimately, the utility of regional assessments depends largely on the success of both regional and local management strategies and their implementation.

Other Procedures for Spatial and Temporal Analysis

The 10 analytical steps described above are not comprehensive. Instead, these steps should be considered an essential starting point, or foundation, for a regional assessment. These steps can be augmented in a variety of ways with other analyses that add detail and depth to the regional assessment in relation to the targeted species.

The following sections identify additional, complementary means by which regional assessments can be used to evaluate conditions for species of concern. These methods are challenging to use, however, in that they require empirical data that are currently lacking for many species. Consequently, it is important to identify the major assumptions on which such analyses are based, both for testing in research and for understanding their implications in management.

Fragmentation, Connectivity, and Patch Size Analyses—Fragmentation, connectivity, and patch size are important concepts of landscape and population ecology that have direct relevance to regional assessments. Unfortunately, these terms are used in myriad ways and often poorly defined by users, leading to misinterpretation and loss of utility (Haila 2002, Villard 2002). For example, each term can be defined in relation to habitats, populations, or both. Moreover, each term can be used generically as a landscape metric, or applied specifically to a particular species or set of species (Fahrig 2002). Consequently, formal definitions for use in regional assessments are needed to avoid misinterpretation.

Accordingly, we suggest that fragmentation, connectivity, and patch size be defined and used in regional assessments to evaluate the configuration of habitats; that is, to evaluate habitat edge relative to area (fragmentation), habitat arrangement (connectivity), and habitat size (patch size). Such measures are useful for regional assessments because they depict the "patterning" of habitats across large spatial extents that can affect species in a variety of ways (Donovan and Flather 2002, Knick and Rotenberry 2002). Definitions for use of these terms to evaluate habitat configuration in regional assessments follow:

- *Fragmentation:* The degree to which habitats are subdivided into smaller and more isolated patches, where subdivisions are measured by the relation between the length of habitat edge and the size of habitat patches. Long length of habitat edge relative to low size of habitat patches denotes high fragmentation, while short length of edge relative to

high size of patches indicates low fragmentation. Many variations of this basic definition are described by McGarigal and Marks (1995).

- *Connectivity:* The degree to which habitats for a species are continuous or interrupted across a spatial extent, where habitats defined as continuous are within a prescribed distance over which a species can successfully conduct key activities (e.g., effective dispersal distance of seeds or juveniles, mean distances moved for foraging, nesting, and brood-rearing), and habitats defined as interrupted are outside the prescribed distance. As an example, Raphael et al. (2001) defined habitats as being "connected" if patches were within one-half the mean dispersal distance for juveniles of a given species; habitat connectivity was then summarized as the percentage of habitat area that was connected for the species, as measured over millions of hectares in each species' range.

- *Patch Size:* The area (hectares) constituting a separate piece of habitat for a species, where the piece is defined as the pixels of habitat adjacent to one another (pixels touching one another on any side or corner), or the piece is defined by some alternative rule set designed specifically for a species. For watersheds or larger spatial extents, the mean or median size of habitat patches present may be a useful summary, in tandem with a display of the frequency distribution of patch sizes.

While the conceptual basis for using these measures of habitat configuration is straight forward, their operational use is not. The following points should be considered if measures of habitat configuration are included in a regional assessment:

- Effects of change in habitat configuration are not well documented for most species of concern (McGarigal and Cushman 2002). Different species respond in different and sometimes contradictory ways in relation to a given spatial configuration of habitats (Haila 1997). Different landscape models, assumptions, and metrics are likely required to assess configuration effects on different species of concern, assuming effects are known.

- Results of fragmentation, patch size, and connectivity analyses will vary with pixel resolution. Use of coarse pixels (Figure 7) results in a "smoothing" of habitats into fewer patches with larger patch sizes and higher connectivity. Use of fine pixels results in more discrete mapping of habitats into smaller, less well-connected patches. The appropriate pixel resolution is the one most compatible with the species' ecology. For example, a coarse pixel resolution is more appropriate for an animal species that moves over large areas and selects habitats with less discrimination than an endemic plant species with stringent, site-specific requirements.

- Measures of habitat configuration are often correlated with measures of habitat abundance (Haila 2002). For example, increased habitat fragmentation invariably reflects decreased habitat abundance. Furthermore, simple measures of habitat abundance often account for substantially more variation in predicting species' extinction than measures of habitat configuration (Fahrig 1997, 2002). Measures of habitat configuration therefore are complementary but secondary to analyses of habitat abundance.

Consideration of Non-vegetative Factors Affecting Species of Concern—Source habitats are defined as characteristics of macro-vegetation that contribute to stationary or increasing rates of population growth for a given species (Wisdom et al. 2000). This definition implicitly acknowledges that factors beyond macro-vegetation can affect population persistence (Figure 9). Consequently, effective management of habitats must proceed in tandem with management of other factors that affect persistence. Knowledge about the negative effects of non-vegetative factors therefore is an important, complementary component to proper management of vegetation identified as source habitats.

Examples of non-vegetative factors that affect species' persistence include (1) over-hunting, over-trapping, poaching, excessive collection for the pet or medicinal trades, or other forms of non-sustainable take; (2) high rates of predation, particularly when changes in habitat predispose species to increased predation; (3) roads or other human disturbances that act as barriers to dispersal, cause avoidance, or disrupt life cycles; (4) indiscriminate, excessive use of pesticides or other chemicals; and (5) anomalies of severe weather or other catastrophes. These examples are not inclusive, but illustrate the diversity of factors that may override the effects of beneficial management of habitat.

Lee (2000) and Marcot et al. (2001) developed the use of Bayesian Networks to integrate the effects of all such variables, biotic and abiotic, which affect species of concern. Raphael et al. (2001) used Bayesian Networks to develop landscape models for a variety of sagebrush-associated species of concern. This form of model performed well as a tool to evaluate landscapes for environmental quality and estimate the probability of regional extirpation for Greater sage-grouse (Wisdom et al. 2002b).

Change Detection Studies—Specification of the desired temporal scale is an important consideration for regional assessments. That is, deciding whether to estimate changes in habitats over time, selecting the proper time periods for estimating such changes (temporal extent), and ensuring that potential biases associated with different methods of estimating conditions at different time periods are reconciled (Noon and Dale 2002). In particular, using different methods to estimate habitats for each time period will affect the spatial grain and accuracy, in turn affecting estimates of habitat change over time. As with spatial scale, the objectives of a temporal analysis determine requirements for extent and accuracy.

By definition, any analysis of risks posed by threats to species or their habitats (e.g., Table 5) is a temporal analysis. That is, identifying sagebrush cover types as being at varying levels of risk from a given threat explicitly assumes that such effects will occur at some point in the future. This time point needs to be specified (e.g., Figures 8 and 10), as risks change with different periods of time over which they are estimated.

The following points may be helpful in considering the use of change detection studies as part of a regional assessment:

- Resources needed for change detection studies are substantial: variables of interest must be estimated at multiple points in time, and consistent methods used to analyze differences over time.

- Narrow time periods may reveal little change in habitat conditions, incorrectly suggesting that change has been minimal. Or, narrow time periods may capture effects of an infrequent but large episodic event, falsely suggesting that change has been substantial.

By contrast, changes measured over multiple time points, spanning longer time periods, are more likely to reveal past dynamics of habitat change that are easier to interpret.

Different methods often must be used to estimate conditions at different time periods. In general, estimates become increasingly coarse in resolution as one goes farther back in time. By contrast, estimates made closer to the present often rely on the same or similar methods of estimating conditions. Differences in methods used for different time points must be accounted for in the analyses and subsequent inferences.

USING RESULTS IN LAND USE PLANNING

Regional assessments are essential in establishing regional management strategies as context for efficient and credible development and implementation of local land use plans. At the same time, regional management strategies can be refined with feedback from local planning. The interaction of regional management strategies with local planning fits the concept of "top-down" and "bottom-up" processes (Figure 4). Both processes are essential in dealing with land use issues that are simultaneously regional and local in scale.

For example, an ecoregion map of risks to sagebrush habitat from powerlines could be invaluable in setting regional management strategies (Figure 11). Based on the regional assessment, the regional strategy could focus on management practices designed to mitigate or reduce the high risk of habitats becoming unsuitable from powerline development. Such strategies might call for rerouting some proposed powerlines that pose pervasive effects that are deemed unacceptable to managers.

Alternatively, effective management of sagebrush habitats in relation to powerline development requires local knowledge of the best management practices deemed to be effective for mitigation. In that way, local management strategies and associated goals, standards, and guidelines are critical for meeting goals of a regional strategy. Moreover, local knowledge can be used to "inform" the regional management strategy about areas where the regional strategy may be more effective than in other areas. Again, this illustrates the adaptive nature of combining "top-down" and bottom-up processes in land management.

Another complementary aspect of regional (top-down) versus local (bottom-up) management strategies is the need to consider species whose habitats can be included in a regional assessment, versus those species' habitats that can be assessed only within local areas. Many species of concern are local endemics, requiring local assessment with the use of fine-scale spatial data or field surveys. Overlaying the results of these local assessments with results for regional assessments is an important part of integrating the needs of local endemics versus species whose needs are assessed over larger areas. Typically, consideration of results from local assessments will allow managers to establish management strategies for small areas, or for specific conditions related to the needs of local endemics. Simultaneously, managers can consider the broad conditions and risks depicted by regional assessments as a complement to local assessments.

Another benefit from regional assessments is the opportunity to project future outcomes and effects of land management on species of concern. One example is the effects analysis of the risk of species extirpation based on the land management alternatives proposed by the FS and BLM in the Interior Columbia Basin (Marcot et al. 2001, Raphael et al. 2001). Projections of

future outcomes can be compared against goals for future management, to determine whether the goals will be met under the land management alternatives (USDA Forest Service and USDI Bureau of Land Management 2000).

Finally, results from regional assessments can be used to develop adaptive management plans in relation to strategies, goals, and expected outcomes from future management. In the scientific world, adaptive management calls for management activities to be developed and implemented as experimental treatments, to be tested through large-scale research experiments (Holling 1978, Walters 1986). Such experimental approaches are particularly helpful when the risks posed from various threats are high, and the scientific certainty about how best to manage the risks is low (Walters 1986). Such is the case for management of sagebrush habitats, where conservation and restoration management is a relatively new field, fraught with challenges of addressing the vast spatial and temporal scales needed to achieve effective recovery (Hemstrom et al. 2002, Monsen et al. in press). Moreover, the high degree of technological uncertainty about the effectiveness of sagebrush restoration complicates the challenges of scale even further (West 1999, McIver and Starr 2001). Regional assessments play a key role under such conditions, as a means of synthesizing the best available scientific information available about species of concern and their habitats, summarized in a manner that can be efficiently and credibly dealt with as part of a research-management partnership.

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